INTERNATIONAL RECOMMENDATIONS FOR X-RAY AND RADIUM PROTECTION

REVISED BY THE INTERNATIONAL X-RAY AND RADIUM PROTECTION COMMISSION AT THE FIFTH INTERNATIONAL CONGRESS OF RADIOLOGY, CHICAGO, SEPTEMBER, 1937.

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INTERNATIONAL RECOMMENDATIONS

1. The dangers of over exposure to X rays and radium can be avoided by the provision of adequate protection and suitable working conditions. It is the duty of those in charge of X-ray and radium departments to ensure such conditions for their personnel. The known effects to be guarded against are :—

(*a*) Injuries to the superficial tissues.
(*b*) Changes in the blood and derangements of internal organs, particularly the generative organs.

The evidence at present available appears to suggest that under satisfactory working conditions, a person in normal health can tolerate exposure to X rays or radium gamma rays to an extent of about 0·2 international röntgen (r) per day or 1 r per week. On the basis of continuous irradiation during a working day of seven hours, this figure corresponds to a tolerance dosage rate of 10^{-5} r per second. The protective values given in these recommendations are generally in harmony with this figure under average conditions.

I. WORKING HOURS ETC.

2. The following working hours etc., are recommended for whole-time X-ray and radium workers :—

(*a*) Not more than seven working hours a day in temperate or cold climates. For workers in tropical climates shorter hours may be desirable.
(*b*) Not more than five working days a week. The off-days to be spent as much as possible out of doors.
(*c*) Not less than four weeks holiday a year, preferably consecutively.
(*d*) Whole-time workers in hospital X-ray and radium departments should not be called upon for other hospital service.
(*e*) X-ray, and particularly radium workers, should be systematically submitted, both on entry and subsequently at least twice a year, to expert medical, general and blood examinations, special attention being paid to the hands. These examinations will determine the acceptance, refusal, limitation or termination of such occupation.
(*f*) The amount of radiation received by operators should be systematically checked to ensure that the tolerance dose is not exceeded. For this purpose, photographic films or small-capacity condensers may be carried on the person.

II. GENERAL X-RAY AND RADIUM RECOMMENDATIONS

3. X-ray departments should not be situated below ground floor level.

4. All rooms, including darkrooms, should be provided with windows affording good natural lighting and ready facilities for admitting sunshine and fresh air whenever possible.

5. All rooms should be provided with adequate exhaust ventilation. In certain climates it may be necessary to have recourse to air conditioning. For rooms of normal dimensions, say 3,000 cubic feet (90 c. metres) in which corona-free apparatus is installed, the ventilating system should be capable of renewing the air of the room not less than six times per hour, while up to ten times may be required when the apparatus is not corona-free. Large rooms require proportionately fewer changes of air per hour than small ones. Air inlets and outlets should be arranged to afford crosswise ventilation of the room.

6. All rooms should preferably be decorated in light colours.

7. A working temperature of about 18°-22° C. (65°-72° F.) is desirable in X-ray rooms.

8. X-ray rooms should be large enough to permit a convenient lay-out of the equipment. A minimum floor area of 250 sq. ft. (25 sq. metres) is recommended for X-ray rooms, and 100 sq. ft. (10 sq. metres) for darkrooms. Ceilings should be not less than 11 ft. (3·5 metres) high.

9. High-tension generators employing mechanical rectification should preferably be placed in a separate room from the X-ray tube.

III. X-RAY PROTECTIVE RECOMMENDATIONS

10. An X-ray operator should on no account expose himself to a direct beam of X rays.

11. An operator should place himself as remote as practicable from the X-ray tube. It should be borne in mind that valve tubes are capable of producing X rays.

12. The X-ray tube should be self-protected, or otherwise surrounded as completely as possible with protective material of adequate lead equivalent.[1]

13. The following lead equivalents, which are based on average conditions, may require to be modified for high-power tubes or considerable distances :—

X rays generated by peak voltages	Minimum equivalent thickness of lead
Not exceeding 75 K.V.	1 mm.
100	1·5
125	2
150	2·5
175	3
200	4
250	6
300	9
350	12
400	15
(600)	(35)

[1] The lead equivalent of a given thickness of protective material is that thickness of lead which is equally opaque to X rays excited at some specified peak voltage.

(A) *Diagnostic Work.*

14. In the case of diagnostic work with other than completely protected tubes, the operator should be afforded additional protection from stray radiation by a screen of a minimum lead equivalent of 1 millimetre.

15. Screening examinations should be conducted as rapidly as possible with minimum intensities and apertures, particularly when fractures are reduced under X rays. Palpation with the hand should be reduced to the minimum.

16. The lead glass of fluorescent screens should have the protective values recommended in paragraph 13.

17. In the case of screening stands, the fluorescent screen should, if necessary, be provided with a protective "surround," so that adequate protection against direct radiation is afforded for all positions of the screen and diaphragm.

18. Screening stands and couches should provide adequate arrangements for protecting the operator against scattered radiation from the patient.

19. Protective gloves, which should be suitably lined with fabric or other material, should have a protective value not less than $\frac{1}{3}$ millimetre lead throughout both back and front (including fingers and wrist). Protective aprons should have a minimum lead value of $\frac{1}{2}$ millimetre.

(B) *Treatment.*

20. In the case of X-ray treatment, the operator is best stationed completely outside the X-ray room behind a protective wall, the lead equivalent of which will depend on the circumstances. In the case of a single X-ray tube excited by voltages up to 200 K.V., the protective wall should have a minimum lead equivalent of 2 millimetres. This figure should be increased in the case of higher exciting voltages or of heavy tube-currents or if the protective value of the X-ray tube enclosure falls short of the values given in paragraph 13. In such event the remaining walls, floor and ceiling may also be required to provide supplementary protection for adjacent occupants to an extent depending on the circumstances. Full protection should be provided in all those directions in which the direct beam can operate.

Inspection windows in screens and walls should have protective lead values equivalent to that of the surrounding screen or wall.

21. In those cases in which an X-ray tube is continuously excited, and treatment periods are regulated by means of a shutter, some form of remote control should be provided for the shutter, to ensure that the operator is not exposed to direct radiation while manipulating the shutter or filter.

22. Efficient safeguards should be adopted to avoid the omission of a metal filter in X-ray treatment, for example, by an interlocking device or by continuously measuring the emergent radiation. Protective screens and applicators (cones) used in treatment to define the ports of entry of X-ray beams should be sufficiently thick to reduce the dosage rate outside the direct field of irradiation to less than 10^{-3} röntgen per second.

IV. ELECTRICAL PRECAUTIONS IN X-RAY ROOMS

23. The floor-covering of the X-ray rooms should be of insulating material such as wood, rubber or linoleum.

24. Where permanent overhead conductors are employed, they should be not less than 9 ft. (3 metres) from the floor. They should consist of stout metal tubing or other coronaless type of conductor. The associated connecting leads should be of coronaless wire kept taut by suitable rheophores.

25. Wherever possible, earthed guards or earthed sheaths should be provided to shield the more adjacent parts of the high-tension system. Unshielded leads to the X-ray tube should be in positions as remote as possible from the operator and the patient. The use of "shock-proof" X-ray equipment, in which the high-tension circuit is completely enclosed in earthed conductors, is recommended. In all cases, however, indiscriminate handling of X-ray tubes during operation should be forbidden. Unless

there are reasons to the contrary, metal parts of the apparatus and room should be efficiently earthed.

26. Main and supply switches should be very accessible and distinctly indicated. They should not be in the proximity of the high-tension system, nor should it be possible for them to close accidentally. The use of quick-acting, double-pole circuit breakers is recommended. Over-powered fuses should not be used. If more than one apparatus is operated from a common generator, suitable high-tension, multi-way switches should be provided. In the case of some of the constant-potential generators, a residual charge is held by the condensers after shutting down, and a suitable discharging device should therefore be fitted. Illuminated warning devices which operate when the equipment is " alive " serve a useful purpose. The staff should be trained in the use of first-aid instructions dealing with electrical shock. If foot switches are used, they should be connected in series with an ordinary switch, and should be so designed that they cannot be locked to keep the circuit " alive," and are not capable of being closed accidentally.

27. Some suitable form of kilovoltmeter should be provided to afford a measure of the voltage operating the X-ray tube.

28. Low flash-point anæsthetics should never be used in conjunction with X rays.

V. FILM STORAGE PRECAUTIONS

29. The use of non-inflammable X-ray films is strongly recommended. In the case of inflammable films, suitable precautions should be taken as regards their use and storage. Large stocks should be kept in isolated stores, preferably in a separate building or on the roof.

VI. RADIUM PROTECTIVE RECOMMENDATIONS

(A) *Radium Salts.*

30. Protection for radium workers is required from the effects of :—

(*a*) Beta rays upon the hands.

(*b*) Gamma rays upon the internal organs, vascular and reproductive systems.

31. In order to protect the hands from beta rays, reliance should be placed, in the first place, on distance. The radium should be manipulated with long-handled forceps, and should be carried from place to place in long-handled boxes, lined on all sides with at least 1 centimetre of lead. All manipulations should be carried out as rapidly as possible.

32. Radium, when not in use, should be stored in a safe as distant as possible from the personnel. It is recommended that the safe should be provided with a number of separate drawers individually protected. The amount of protection should correspond to the values given in the following table. These values, which are based on working conditions where there is proximity to radium, may be reduced for larger working distances.

Maximum quantity of radium element	Thickness of lead
0·05 gm.	5 cm.
0·2	8·5
0·5	10
1·0	11·5
2·0	13
5·0	15
10·0	17

33. A separate room should be provided for the " make-up " of screened tubes and applicators, and this room should only be occupied during such work.

34. In order to protect the body from the penetrating gamma rays during handling of radium, a screen of not less than 2·5 centimetres of lead should be used, and proximity to the radium should only occur during actual work, and for as short a time as possible.

35. The measurement room should be a separate room, and it should preferably contain the radium only during its actual measurement.

36. Nurses and attendants should not remain in the same room as patients undergoing radium treatment with quantities exceeding $\frac{1}{2}$ gramme.

37. All unskilled work, or work which can be learnt in a short period of time, should preferably be carried out by temporary workers, who should be engaged on such work for periods not exceeding six months. This applies especially to nurses and those engaged in " making-up " applicators.

38. Radium containers should be tested periodically for leakage of radon. Prejudicial quantities of radon may otherwise accumulate in radium safes, etc., containing a number of leaky containers.

39. Discretion should be exercised in transmitting radium salts by post. In the case of small quantities (less than 10 milligrammes of radium element) it is recommended that the container should be lined throughout with lead not less than 3 millimetres thick, while for quantities between 10 and 50 milligrammes of radium element, the lead container should be supported in the centre of a box with a minimum dimension of 30 centimetres. Packages containing more than 50 milligrammes of radium element are preferably sent by rail or hand under suitable conditions of protection.

(B) *Radon.*

40. In the manipulation of radon, protection against beta and gamma rays is required, and automatic or remote controls are desirable.

41. The handling of radon should be carried out, as far as possible, during its relatively inactive state.

42. Precautions should be taken against excessive gas pressures in radon plants. The escape of radon should be very carefully guarded against, and the room in which it is prepared should be provided with an exhaust fan controlled from outside the room.

43. Where radon is likely to come in direct contact with the fingers, thin rubber gloves should be worn to avoid contamination of the hands with active deposit. Otherwise the protective measures recommended for radium salts should be carried out.

44. The pumping room should preferably be contained in a separate building. The room should be provided with a connecting tube from the special room in which the radium is stored in solution. The radium in solution should be heavily screened to protect people working in adjacent rooms. This is preferably done by placing the radium solution in a lead-lined box ; the thickness of lead recommended being according to the table in paragraph 32.

(C) *Radium-Beam therapy.*

45. The risks to the operator attendant on the use of large quantities of radium in radium-beam therapy may be largely obviated if some system of remote control is adopted by which the radium is only introduced into the " bomb " after the latter has been adjusted in position on the patient. If such arrangements are not available the importance of expeditious handling is stressed.

46. Rooms used for radium-beam therapy should provide adequate protection for adjacent wards and rooms in permanent occupation.

The following minimum lead thicknesses are required to secure a tolerance dosage-rate of 10^{-5} röntgen per second at various distances from different quantities of radium.

The distances corresponding to the tolerance dosage rate in the absence of lead are also given.

Quantity of radium element (0·5 mm. Pt. screen)	Thickness of lead to give tolerance dosage rate at the following distances from radium source				Tolerance distance with no lead
	50 cm.	1 metre	2 metres	5 metres	
gm.	cm.	cm.	cm.	cm.	metres
1	9·0	6·0	3·0	—	4·5
2	10·5	7·5	4·5	1·0	6·5
5	12·5	9·5	6·5	2·5	10·5
10	14·0	11·0	8·0	4·0	14·5